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MULTI OBJECTIVE STUDY OF BARRIER COATINGS IN GAS TURBINE CHAMBERS AND BLADES WITH CFD

D. MANOJ CHANDRA*1 K CHANDRA SEKHAR*2 Dr B. SUDHEER PREMKUMAR

1*. M. tech Student, Department of Mechanical Engineering, 1*QIS College of Engineering and Technology Ongole, Prakasam Dist, A.P – 523272

2*. Associate Professor, Department of Mechanical Engineering, 1*QIS College of Engineering and Technology Ongole, Prakasam Dist, A.P – 523272

3* Professor, Department of Mechanical Engineering, JNTUCEH, JNTU Hyderabad

Email: manojchandra.246@gmail.com

ABSTRACT:
The most advanced technology in all aspects is available for modern gas turbines because of their extreme operating conditions, construction materials are not the exception. It has already been stated at the most difficult point at the turbine inlet, as it is associated with a range of difficulties such as extreme temperature 1400o-15000c High-pressure , high-speed vibration vibrating low circulatory region so that more internalization can be achieved by various enhanced serpentine paths within the blade and heat extraction out of the blades. Due to the numerous improvements in heat transfer and pressure drop in the different blades and vans of a gas turbine, it is not a considerable effort by ANYS CFD to locate the high heat stream areas in the areas of the blade profiles in order to minimize laminations to a particular boundary for economies of the cycle. Their implementation is considered by future factors

Keywords: multi objective study, barrier coatings heat flux CFD

1.0 INTRODUCTION
The main components in the power plant industry is the gas turbines. Gas turbine blades operate in a hostile environment which causes damage to thermal and mechanical stress. Each blade defect has an appalling impact on motor output. Research shows that more than 40 percent of damage to gas turbines is due to blade failure Thermal stress is an important parameter of turbine blades design, based on temperature distribution and a challenge for engineers to increase turbine blade resilience against temperature effects. The use of super alloys, refreshment and thermal barrier (TBC) coatings, as shown by studies, are important factors that can enhance layer life. Super alloys are metal alloys made in the 1900s that are ideal for working in high-temperature areas due to the mechanical characteristics. Nickel base super alloy is very robust, suitable for high temperatures, but it ensures that refrigeration methods, in addition, the average temperature and temperature gradients in the blade should be controlled such as the film cooling, inner cooling.

Gas Turbine:
The energy from a combustion stream is produced by a rotating gas turbine resulting from the ignition of the compressed air and fuel (whether a gas or a fluid, especially natural gas). It has an upstream integrated compressor and a downstream turbine and a (including ignitor) intermediate chamber assembly. The gas stream in the fuel is driven by the air mixed together with the fuel and ignited. Combustion increases the temperature, velocity and volume of gas flow. It crosses a pine over the turbine blades and spins around the turbine and drives the compressor.

Characteristics of TBC:
There are certain characteristics that a good Thermal Barrier Coating should satisfy. They are listed as follows:

- Low melting point: the cover must be melting low enough that it resists high temperatures without melting.
- Low thermal conductivity: The coating will have very low thermal conductivity such that there is a noticeable decrease in the coating temperature.
- Low density: In order to reduce payload, the coating content should be low density and weight.

APPLICATIONS OF TBC:
Direct vapor deposition is used mainly to manufacture coatings on complex surfaces. This may create coatings on the inner surfaces of machine components that cannot be reached by other methods.

Turbine Blade Applications:

The internal surfaces of the combustion Chambers in Airplane Gas Turbines have extensively been covered using thermal barrier coatings due to their low absorptivity and thermal conductivity. The requirement for TBC is much higher in turbines than it is in the combustor. The strong convective heat fluxes in the turbine contribute to large mechanical thermal loads in ceramic coats in both temporary and steady conditions. In the turbine 's hot points, the amber of and high metal temperatures are 50 to 100 ° C higher than the combustion engine. The environmental resilience of the connective coat is therefore strongly demanded. Plasma sprayed coats are subject to processes such as sintering and change of phase at these elevated surface temperatures.

2.0 LITERATURE REVIEW

Aqeel Jomma Athab et al [1] Heat transfer and pressure distribution tested in the gas turbine fan on ten circular cooling lines. This simulated the application of thermal transfer with soft industrial equipment. The maximum thermal transmission coefficient is at the stepping point on the top and, according to this article, the lowest is on the trailing edge. The mid range trailing edge has the maximum temperature and voltage.

Aram Mohammed Ahmed [2] Several analyzes have been conducted on the high pressure turbine blade in both steady state and non-stead conjugated heat transfer (CHT). They also used ANSYS CFX to address the strong and flow domain problem simultaneously. A 3D model to test the temperature distribution across the body of the blade. Results contrasted between both steady and unstable state.

Asok Kumar, N., S.R. Kale [3] The thermal transient study of the thermal barrier coated blade of the gas turbine has been described. The blade material was Inconel-718 and the temperature rose to 1000 ° C. Effects with a thickness of 0.5 mm TBC are addressed on operating temperature. In the numerical example studied applications of 0,5 mm thickness YSZ thermal barrier coating significantly reduce the operating temperatures by about 18%.

Asok Kumar, N., S.R. Kale [4] Visual inspection and final factor review examined the failure of the first-stage gas turbine container. The failure of the big cooling bucket was a crucial cause of the separation of the bucket segment and caused severe thermal load to deteriorate the microstructure of the neighboring area.

Bacos, M.P., Dorvaux [5] The aviation gas turbine has grown in the last half-century into the most complex technology worldwide, and its effect on mankind has been surprisingly positive. Jet-powered aircraft have provided the USA with an unparalleled air power superiority to foster world peace and support. Huge turbofan-powered and commercial aircraft have spread around the globe, growing the environment much as clean gas turbines are used worldwide to produce electricity.

3.0 METHODOLOGY

The rotor of the gas turbine works at higher temperatures. More temperature is protected by thermal barrier coating These coatings are used in combustion blades and lead vehicles. These coatings may be protected. The rim of the gas turbine blade is coated with a weak thermal conductive content. Such coating not only decreases the component's metal temperature and lowers the oxidation risk of the coating applied to the blade surface, which thus delays due to oxidation loss. Such coating reduces the metal temperature of the component. The coolant dissipates the heat on the blade of the turbine, which is cooling technology. The coolant runs at a high rate and reduces the temperature of the rotor surface by expanding the thickness of the turbine blade. This technique prevents high temperatures for the edge. In today's decades, various types of cooling methods are used: internal air cooling, external air cooling and liquid spray cooling.

CAD Model:-

The image was then stranded to 150 mm in length. A cooling channel was designed according to the requirements specified in a square 12 mm length and 12 mm breadth transverse portion of the cooling channel. The cooling canal was constructed from 0.6 mm thick matrix-shaped ribs on the top and bottom side and spaced between the ribs, around 7.488 mm in pitch {p}. The matrix arrangement consisted of 15 such ribs. It has been determined that the hydraulic channel diameter is 24 mm.

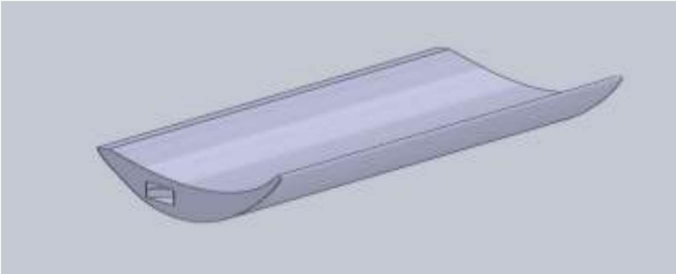

Figure: 3.1 CAD model of the turbine blade in SOLID WORKS

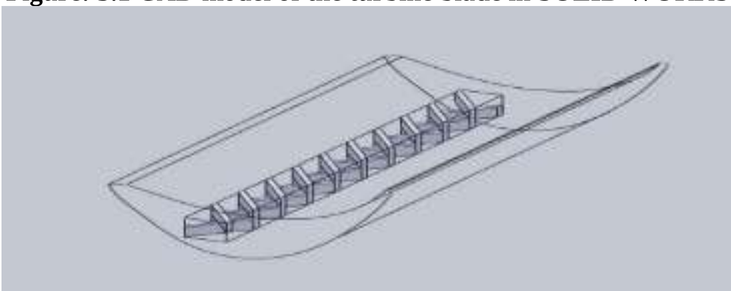

Figure: 3.2 Wireframe structure

CFD ANALYSIS OF GAS TURBINE BLADE;

Computational fluid dynamics is a scientific field, which uses numerical techniques and matrices to solve complex problems in engineering to simulate fluxes and thermal problems The most popular approach used in CFD is the approach of finite volume, which incorporates the finite element and the finite difference methods. The fundamentals of CFD however lie in the calculation of the navier stocks. In the initial stages of the project, CFD simulation will be used to simulate air flow and quantify wing drag particularly for hyper-sonic aircraft and highly maneuverable aircraft.

Figure:3.3 meshed view

Set Up: -

The blade material was selected to be an Inconel 718 nickel super-alloy, commonly used in aero-space applications. The properties of materials are imported from and described below

Material Name	Thermal Conductivity	Density {ρ}	Specific Heat Capacity {Cp}
Inconel 718	11.4 W/m-K	8190 kg/m3	435 J/kg-K

Boundary conditions:

For the ribbed matrix channel five different mass transmission rates were used as stated. Just one flow rate of m=0.01 kg / s was used for smooth channel relative to the ribbed matrix channel.

- Mass flow rates{m} :- 0.01 kg/s; 0.02 kg/s; 0.03 kg/s; 0.04 kg/s ; 0.05 kg/s
- Convective Heat Transfer Coefficient{h} of outer surface of blade :- 1000 W/m2 -K
- Free-stream temperature of the surroundings {Tfree}:- 1700 K(approx)
- Temperature of air at the inlet {Tinlet}:- 400 K(approx)

4.0 RESULTS AND DISCUSSIONS

For a gas turbine engine, the rotor was working at a higher temperature than the surface content melting point. The continued healthy operation of gas turbines with high efficiency is a significant factor in the cooling of gas turbine blades. Various methods have been proposed for cooling blades, one of which is to have radial hole in the blades to transfer high-speed cooling air

For m = 0.01 kg/s; v= 50.93 m/s,

m = 0.02 kg/s; v= 100.78 m/s,

In the study of the variation in temperature and velocity along the surface of the blade as well as the field of the fluid, the following velocity and temperature contours were found.

- Temperature contour on the side walls, inlet and outlet surfaces.
- Temperature contour on the bottom surface of the turbine blade.
- Velocity contour at inlet of the fluid domain.
- Velocity contour at the outlet of the fluid domain.
- Temperature contour along the fluid domain.

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And so, in the fluid sector, the following graphs are drawn up against 15 selected z-coords to evaluate their variance for the mass fluid concentrations described above.

- Trend of average Nusselt number.
- Trend of average Heat Transfer Coefficient.
- Trend of inner Wall temperature along the fluid domain.

Temperature and Velocity Contours:

For m = 0.01 kg/s

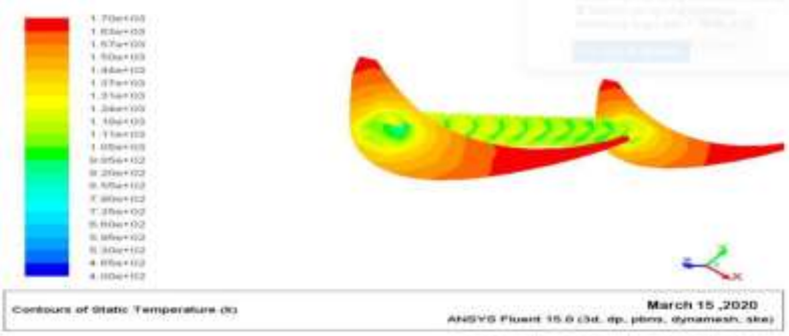

Figure: 4.1 Temperature contour on side walls, inlet and outlet

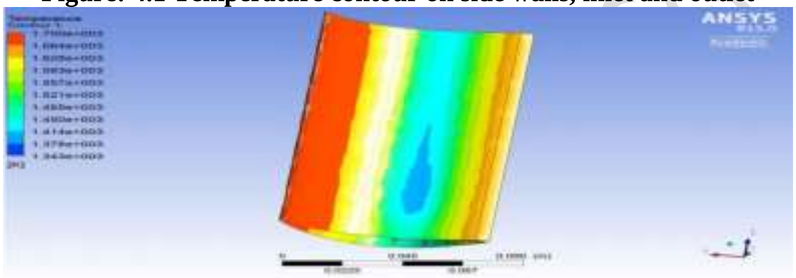

Figure: 4.2 Temperature contour on the bottom surface of the blade

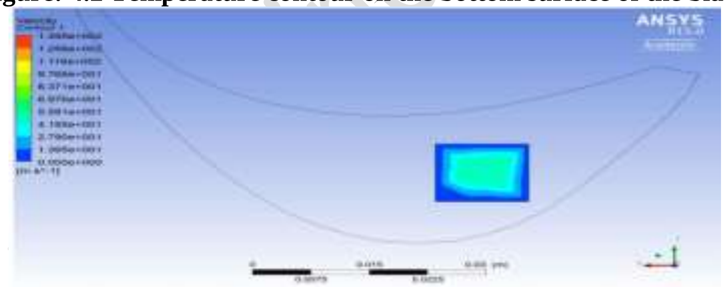

Figure: -4.3 Velocity- contour at inlet

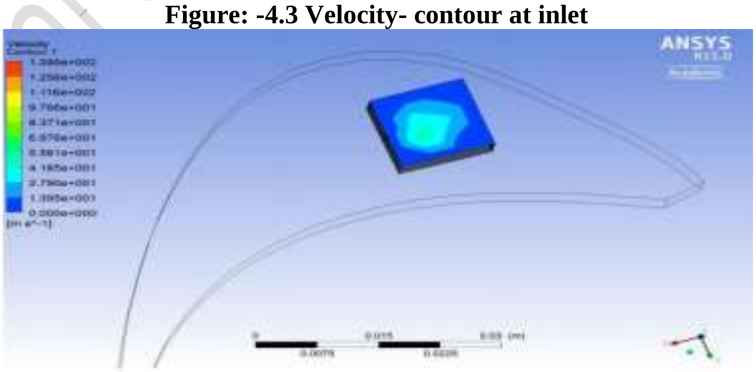

Figure: - 4.4 Velocity-contour at outlet

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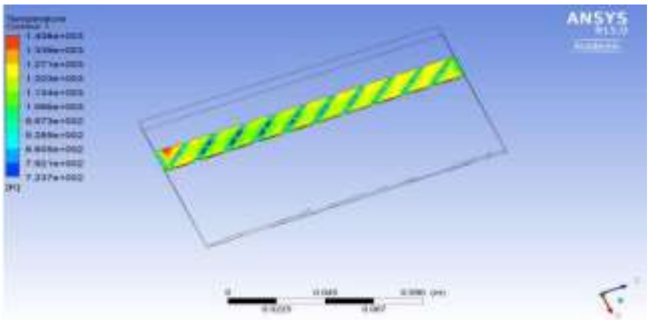

Figure: 4.5 Temperature contour along the fluid domain

For m = 0.02 kg/s:

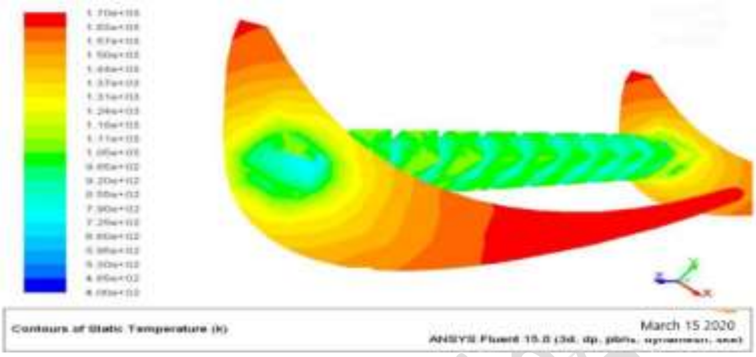

Figure: - 4.6 Temperature contour on the side walls, inlet and outlet

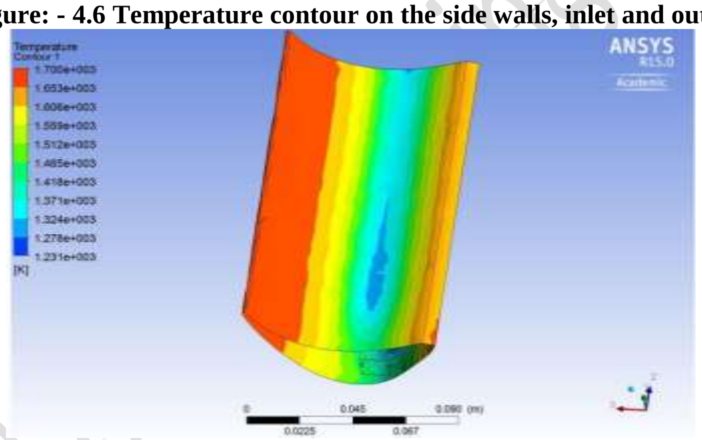

Figure: 4.7 Temperature contour on the bottom surface of the blade.

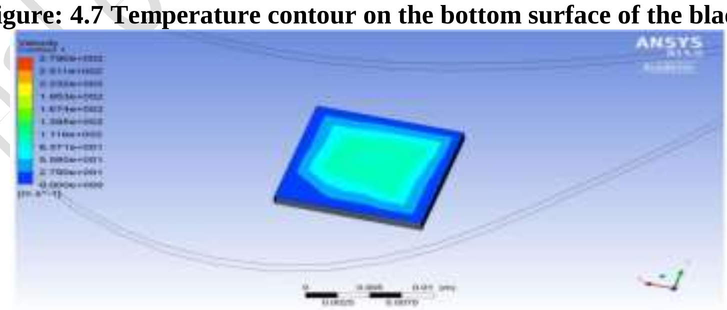

Figure: 4.8 Velocity-contour at inlet.

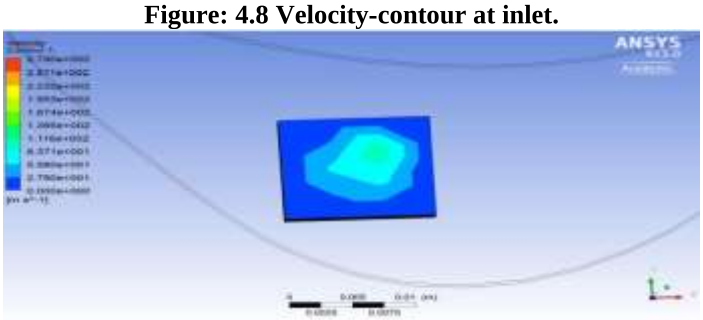

Figure: - 4.9 Velocity-contour at outlet

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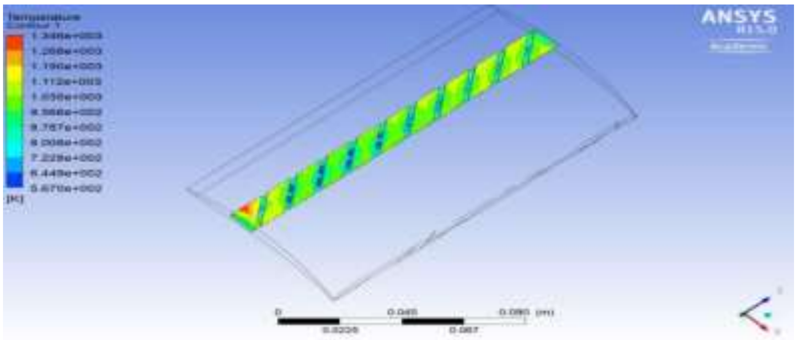
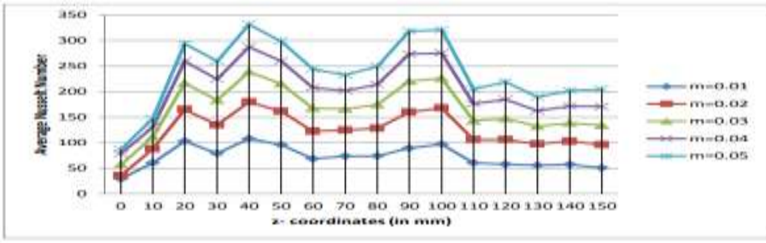


Figure: 4.10 Temperature contour along the fluid domain



Graph 4.1 Plot between Average Nusselt number and chosen z-coordinates.

The average co-efficient and maximum heat transfer rate m=0.01 kg / s. The argument is therefore shown that the ribbed matrix channel increases thermal transport between the cooling air and the blade and hence increases cooling Such an average and Nusselt transmission coefficient is increasing as mass flow is increasing.

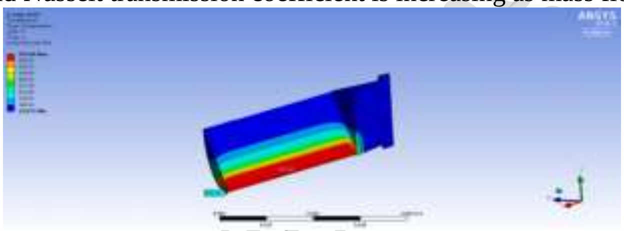


Figure: 4.11 Thermal plot for 100µm

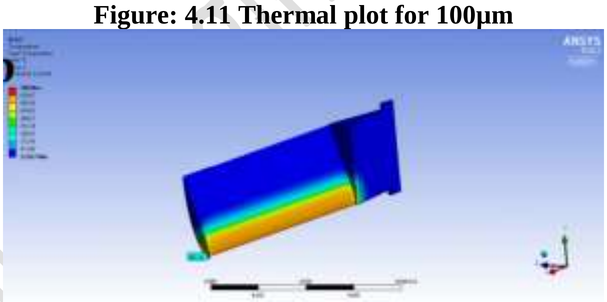


Figure 4.12 Thermal plot for 200µm

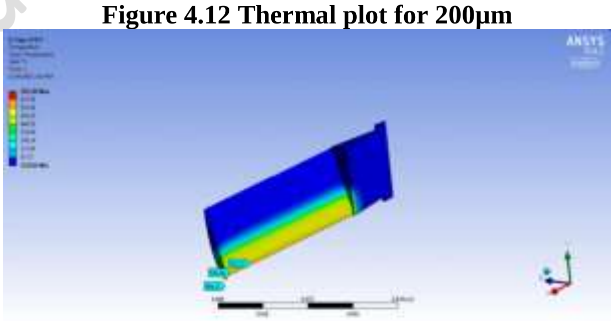


Figure: 4.13 (a)Thermal plot for 300µm

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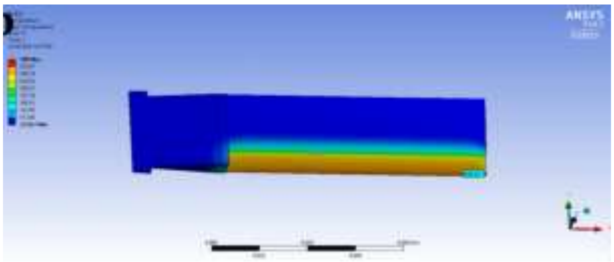

Figure 4.14 Thermal plot for 400μm.

The thermal plots obtained demonstrate the inclusion of further insulation on the surface of the blade limits the heat transfer / heat flow. The thickening of the insulation is smaller because the heat transfer field is a continuous one

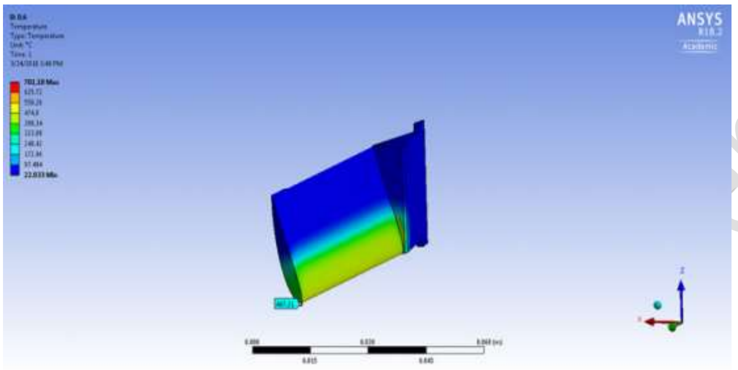

Figure: 4.15 Thermal plot for 500μm

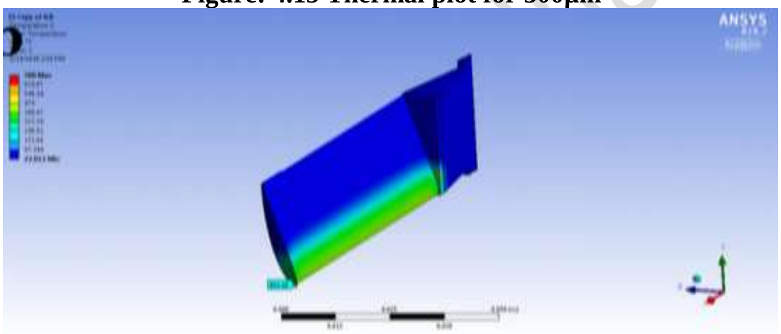

Figure: 4.16 Thermal plot for 600μm

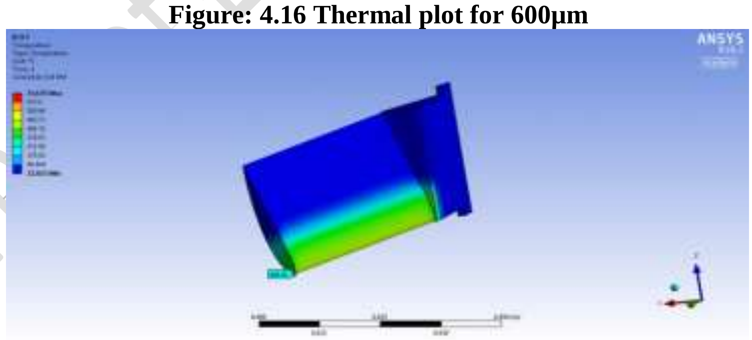

Figure: 4.17 Thermal plot for 700μm;

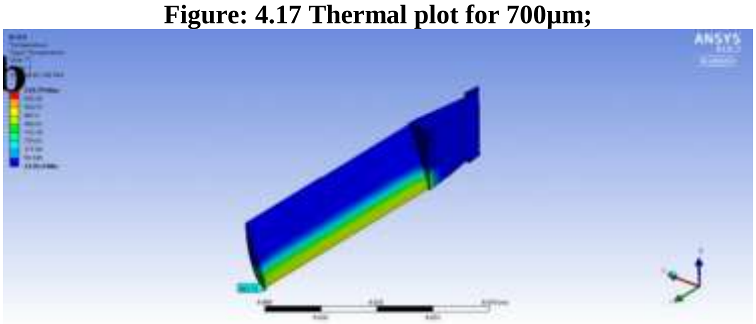

Figure: 4.18 Thermal plot for 800μm.

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The thermally analyzed heat flux maps have been obtained. Heat stream sections from 100 microns to 800 microns of variable thickness are shown in the Fig.

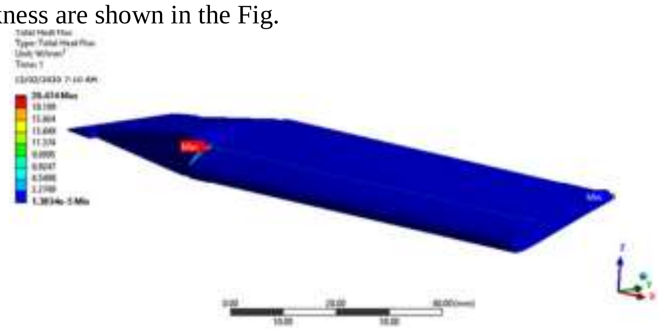


Figure: 4.19 Heat flux plot for 100μm

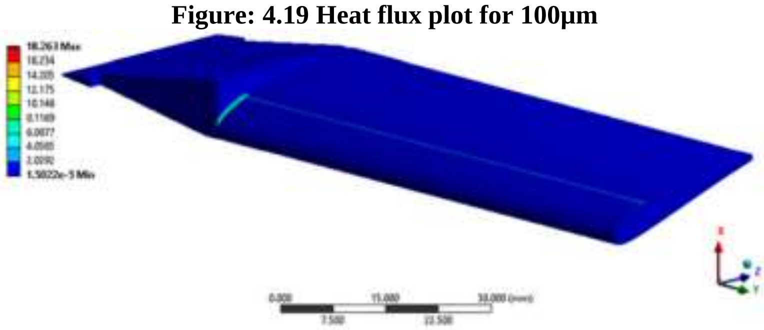


Figure: 4.20 Heat flux plot for 200μm

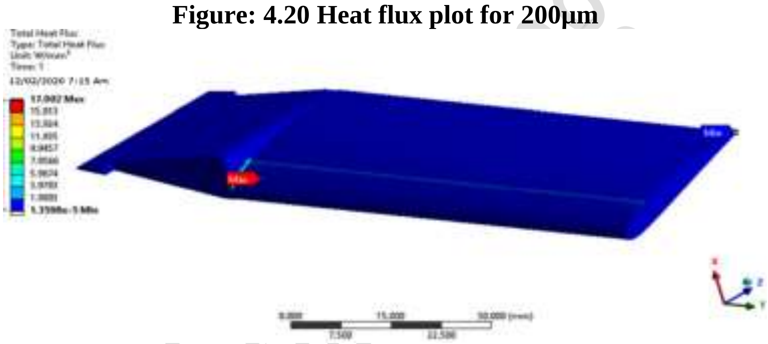


Figure: 4.21 (a) Heat flux plot for 300μm

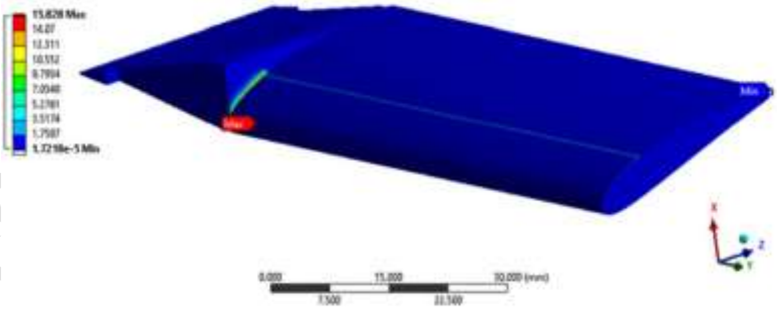


Figure: 4.22 Heat flux plot for 400μm.

The heat flow plots obtained demonstrate that they obey the same pattern as the thermal plots. The heat distribution increases to a certain amount. Then the thickness of TBC decreases further.

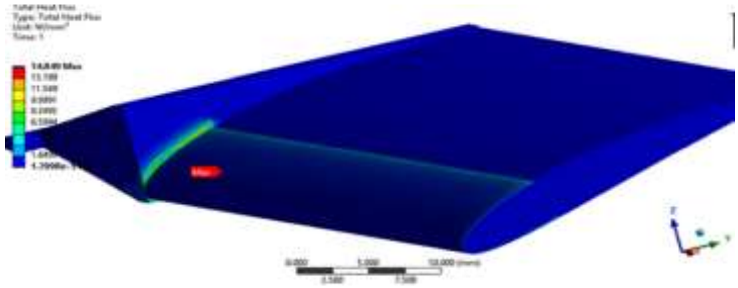


Figure: 4.23 (a) Heat flux plot for 500μm

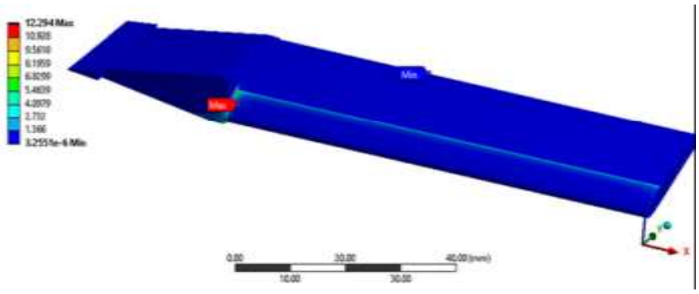
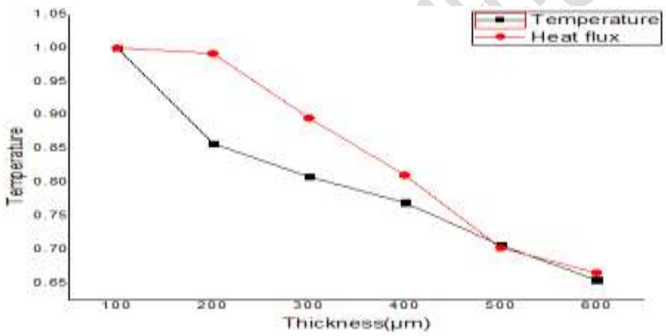


Figure: 4.24 Heat flux plot for 600µm.

The last step is mathematically maximizing the thickness. This change is rendered on the basis of each thickness' temperature, heat flow and costs. The fact that all parameters have different units is tedious. Hence, one of the most basic methods of classical nonlinear optimization has been introduced. It involves the normalization of parameters and the achievement of the optimal value from the diagram
.

Table: Normalized values for each thickness

Thickness(µm)	Temperature	Heat flux
100	1	**1**
200	0.85796	0.991706
300	0.80856	0.895801
400	0.77023	0.81098
500	0.70685	0.70283
600	0.65506	0.66567



Graph: Coated turbine blade different thickness variations

Now a graph is drawn by taking the thickness values on the "x" axis as well as the normalized temp, heat flow and expense values on the "y" axis. The intersection point of these three curves on the map gives the value of TBC 's optimum thickness. The thickness of the thermal layer of the gas blades covering. No attempt to maximize TBC 's thickness has been made thus far. Therefore, the optimum thickness of TBC was found taking into account key factors like temperature, stress and costs in different thicknesses. Studies have shown that zirconium is partly stabilized as the strongest TBC material. The temperature and heat flow plots were obtained after study of various thicknesses. An analysis was carried out and an optimal thickness of 550µm was found.

CONCLUSION:

The combined experimental and analytical research investigated the degradation, through absorption of aluminum particles in a single-stage motor, of the exposed thermal barrier blade (TBC) surfaces Tests were undertaken to determine the erosion rate and recovery features in various impact environments during the experimental study. Experimental findings show that the rate of erosion increases with an increased slope, velocity and temperature. Erosion levels on the stator and rotor blade surfaces of the industrial turbine as the seeding of the particles happens just in 5 percent of the length of the span by hub and jack. TBC erosion is observed almost entirely on the stator suction side in these small lines. As in the previous findings with even particulate absorption, the maximum level of corrosion is at the case at the trailing edge of a suction edge of the stator blade and at the suction edge at the rotor rim. Nevertheless, at the edge of the back of the stator pressure surface there will be area of TBC erosion. Another theory has been checked here, by increasing the flow rate for the above flow conditions in pursuit of an optimum distribution of weight. The phenomenon was inconclusive, so that no maximum mass flow could be reached. With the elevated heat flux values, the fluctuations in the thermal transference coefficient and the Nusselt number are monotonous.

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